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Subject: FCC Technological Advisory Council II, Fourth Meeting Report

To: Members of the FCC TAC

Attached is Report: Fourth Meeting of FCC Technological Advisory Council II. The Chairman of the TAC has approved this report. The meeting was videotaped and that tape serves as the official minutes. This report, prepared to facilitate and document the ongoing work of the TAC, contains an encapsulated version of the meeting and is being posted on the public web site.

/s/
Robert W. Lucky
Chairman
FCC TAC

/s/
Jules A. Bellisio
Executive Director
FCC TAC

Report: Fourth Meeting of FCC Technological Advisory Council II

0.0 Executive Overview

The Federal Communications Commission Technological Advisory Council held the fourth meeting of its second two-year cycle on Friday April 26, 2002 in Washington, D.C. (FCC TAC II, Meeting 4). As described in previous meeting reports, the Council is to provide scientifically supportable information on those emerging technologies likely to impact the work of the FCC. The Council has thirty-two members who were selected because of their professional and technical expertise, some of whom participated in the first TAC.

The TAC is currently organized into four working groups to address spectrum management, optical networking, consumer and home networking, and access to telecommunications for the disabled. Groups worked between the meetings and expanded on each area during roundtable discussions at this meeting.

Spectrum management includes issues associated with the noise floor, software defined radios (SDRs), ultrawideband (UWB), and the proposal previously made by the TAC for the Intelligent Radio "Bill of Rights." A presentation about the SDR reinforced the notion that the TAC has discussed before, that the SDR is a key technology enabler for next generation spectrum management. Invited speaker David P. Reed challenged the idea that spectral capacity is intrinsically a limited resource. He presented plausibility arguments to show that with emerging technologies, especially multihop ad-hoc networking, capacity can be made to grow with the number of users. This extraordinarily valuable, albeit counterintuitive, benefit will only occur if innovative management and operational philosophies can be adopted. The TAC has been working on those changes that might be proposed to make such ideas a workable reality, assuming that many of the technological problems relative to spectral sharing and spectrum reuse can resolved. Closely related to interference and spectral reuse is the issue of the level of the noise floor as it currently exists. A TAC-commissioned study to characterize the noise environment continues apace and a final report is expected at the next meeting.

The *optical networking* group provided an overview of major and emerging broadband access technologies based on a five-hour tutorial recently presented to the Commission. The tutorial reviews broadband access technologies that could potentially be used to extend the reach of broadband in the US. Fourteen technologies with access applications and architectures are profiled. Each technology's description includes basic facts about its performance, applications, architecture, advantages, and challenges. An ongoing survey of broadband deployment elsewhere in the world looks at operating practices and lessons learned. The group is also reviewing the status of industry standards on optical interconnects including those agreements needed to interconnect the optical networks of two or more providers. They will flag any issues that may be of concern to the Commission.

Interoperability between residential systems and intelligent networked appliances are key concerns of the *consumer and home networks group*. A presentation on the wireless personal area network (WPAN) described how wireless technology might replace the planning and installation of the scramble of interconnecting consumer electronics cables in the home. An important issue associated with home entertainment is that of content protection and rights management. There was a description of the technology behind a controversial proposal which would require each final display device to contain technology capable of first determining the rights management status of the content the user intended to play, and then intervening in the presentation in some way as specified the rights holder.

Work on *access to telecommunications for the disabled* is centered on the problem of making designers aware of barriers that can occur as media and information technologies advance and evolve. It is the question of what we can do proactively to prevent the losing of access to content as technologies change. The group expects to go forward with creating a document that would be helpful for technologists in the future. An important issue to be addressed is the preservation of features that have already been introduced to help the disabled but could be lost as new technology is substituted for old. Features and functionalities that need preservation or substitution as technology advances will identified and reported in engineering journals so that there will be a higher probability that future technologies can be launched with accessibility built-in from the start.

This fourth meeting was originally planned for Wednesday March 20, 2002 but was rescheduled at the request of the Commission. The next formal TAC meeting is scheduled for Wednesday June 12, 2002.

Prepared by J. A. Bellisio

Approved by R.W. Lucky May 24, 2002

Report: Fourth Meeting of FCC Technological Advisory Council II

1.0 Introduction

As announced, the fourth meeting of the Federal Communications Commission Technological Advisory Council II (FCC TAC II, *or TAC*) took place on Friday April 26, 2002 at The Portals, 445 12th Street, SW., Washington, D.C. Designated Federal Officer (DFO) Mr. Jeffery Goldthorp, Chief of the Network Technology Division, Federal Communications Commission, opened the meeting. The TAC is chartered for two years at a time, and this meeting was the fourth one of its second two year cycle. The mission and operating principles of the TAC were described in the Report of the First Meeting of the TAC (April 30, 1999), available on the FCC web site at http://www.fcc.gov/oet/tac/report990430.doc. At this meeting, working groups presented findings developed since the last meeting and used them as a basis for the open discussion of items of interest to the Commission.

The general items for ongoing TAC consideration, as requested by the Commission, fall into several major areas: spectrum management, optical networking, access to telecommunications for the disabled, consumer and home networking, and network security. Each of these areas is explained in more detail in this report. It should be understood that the topic areas are intentionally broad and subsume all of the interest areas of the previous instantiation of the TAC. Working groups and chairs for each of four groups have been active since the first meeting of TAC II addressing the main topics of interest to the Commission. *Annex 5* lists the chairs of each group and TAC members who are participating.

This report is a reorganization and distillation of discussions at this fourth meeting of TAC II written to facilitate the ongoing work of the Council. A complete videotape of the meeting serves as the verbatim minutes (*see Annex 1*). This report reviews the presentations and remarks made at the open meeting and draws on some of the drafts prepared between meetings, but does not, per se, necessarily represent the final recommendations of the TAC as a whole.

This meeting was originally planned for Wednesday March 20, 2002 and was rescheduled at the request of the Commission. The next formal TAC meeting is scheduled for Wednesday June 12, 2002. The dates of subsequent general meetings are September18, 2002, and December 4, 2002.

2.0 Agenda as Announced

TECHNOLOGICAL ADVISORY COUNCIL II

Agenda –Fourth Meeting
Friday April 26, 2002
Federal Communications Commission Meeting Room
The Portals, 445 12th Street, SW
Washington, D.C.

10:00 AM- **Opening**	**Jeffery Goldthorp, DFO (FCC Designated Federal Officer)**
10:05- **Introductions and Opening Remarks**	**Commission Representatives, Robert Lucky, Chairman, and TAC Members**
10:15- **How Wireless Networks Scale: The Illusion of Spectrum Scarcity**	**David P. Reed**
10:55- **Software Radio: Enabling Dynamic Spectrum Management**	**Vanu Bose**
11:35- **Discussion on Spectral Issues**	**TAC Members**
12:00- 12:50 PM	**-Break-**
12:50- **Broadband Access Roadmap**	**Stagg Newman**
1:00- **Optical Networking Work Plan**	**Stagg Newman**
1:20- **Wireless Media Alliance**	**John Barr**
1:40- **Digital Copyright Technologies**	**Andy Setos**
2:00- **Accessibility Solutions for People with Disabilities**	**Larry Goldberg**
2:40- **Security Issues**	**TAC Members**
2:45- **Working Group Breakout Sessions**	**TAC Members**
3:00 PM- **Adjourn**	**Jeffery Goldthorp, DFO**

3.0 Membership of the Technological Advisory Council, *FCC TAC II*

Except as indicated (*), all of the following were present at the TAC II fourth meeting:

TAC Chairperson:

Robert W. Lucky - Corporate Vice President, Applied Research, Telcordia Technologies

TAC Executive Director

Jules A. Bellisio - Principal Consultant, Telemediators, LLC. (Telcordia Representative)

Members of Council:

*Kwame A. Boakye - Vice-President, Technology, Harris Corporation

*Fred M. Briggs - Chief Technology Officer, WorldCom, Inc.

*Susan E. Estrada - President and Founder, Aldea Communications, Inc.

David J. Farber - Professor, University of Pennsylvania

*Bran Ferren - Co-Chairman and Chief Creative Officer, Applied Minds, Inc.

*Larry Goldberg - Director of the Media Access Group, WGBH

Richard R. Green - President and CEO, CableLabs

Eric C. Haseltine - Executive Vice President of Research and Development, Inc., Walt Disney Imagineering

Dale N. Hatfield - Director of the Interdisciplinary Telecommunications Program, University of Colorado at Boulder

Christine Hemrick - Vice President, Strategic Technology Policy, Cisco Systems, Inc.

Dewayne L. Hendricks - Chief Executive Officer, Dandin Group, Inc.,

Charles L. Jackson - Independent Consultant

Kevin Kahn - Intel Fellow, Director, Communications Architecture

Kalle R. Kontson - Vice President, IIT Research Institute, Division Manager, Center for Electromagnetic Science

Gregory D. Lapin - Chair, ARRL RF Safety Committee

Paul F. Liao - Chief Technology Officer and President, Panasonic Technologies, Inc.

*Wah L. Lim - Independent Consultant

Willie W. Lu - Principal Wireless Architect, Siemens-Infineon

*David C. Nagel - President and Chief Executive Officer, Platform Solutions Group, Palm, Inc.

*Kevin J. Negus - Chief Technology Officer and Vice President of Business Development, Proxim, Inc

Stagg Newman - Senior Telecommunications Practice Expert, McKinsey and Company

*M. Niel Ransom - Chief Technology Officer, Alcatel USA

Dennis A. Roberson - Corporate Vice President and Chief Technology Officer, Motorola

*Andrew G. Setos - Executive Vice President, News Technology Group

*Nitin J. Shah - Executive Vice President for Business Development and Strategy, ArrayComm, Inc

*Gerald Sharp - Vice President and Chief Technology Officer, ionex telecommunications

Barry Singer - Senior Vice President, Philips Research, Managing Director, Philips Research USA

*Jessica Stevens – Chief Executive Officer, Telegen Corp.

Gregg C. Vanderheiden - Professor/Director, University of Wisconsin, Madison

Robert M. Zitter - Senior Vice President, Technology Operations, Home Box Office

Designated Federal Officer

Jeffery Goldthorp - Chief of the Network Technology Division, Federal Communications Commission

(= **Not present at this meeting**.)*

Annex 2 of this report gives member e-mail information, and *Annex 3* lists FCC staff contacts. Member biographies can be found in Report: First Meeting of FCC Technological Advisory Council II, *Annex 2*. (http://www.fcc.gov/oet/tac/TACII_report6.doc)

About 30 members of the public were present at the meeting and comments from the public are reported as appropriate. The meeting was webcast, videotaped, and carried by closed circuit television throughout the Commission's offices. Live RealAudio access to the TAC meeting was made available through the FCC web site at: http://www.fcc.gov/realaudio/mt042602.ram . It is expected that future TAC meetings will be available from the http://www.fcc.gov/realaudio/ site.

4.0 Summary of Remarks by Representatives of the FCC

Jeffery Goldthorp, who started in November at the Commission and is now the Designated Federal Officer for the TAC, welcomed everyone to the FCC. Edmond Thomas, recently joining the FCC as chief of OET was introduced to the group. Biographies of both are in *Annex 4* of this report.

5.0 Topics of Interest to the Commission and for TAC Consideration

At the request of the Commission, the TAC is focusing on several major subject areas, spectrum management, optical networking, access to telecommunications for the disabled, consumer and home networking, and network security. The spectrum group includes issues associated with the noise floor, software defined radios and ultrawideband - all topics considered by the last TAC group and the technological enablers that form the solution to the overarching problem of spectrum usage. Because optical networks demand broadband connections to final users to realize their full potential, the evolution of broadband access using *all* available technologies is under the umbrella of the optical group. The consumer networking group is looking at the total problem of interconnection everywhere in the consumer domain, not just in the home. Network security is understood to include issues of integrity, confidentiality of telecommunications and the technical enablers for the management of content rights. Analysis of network security issues, originally expected to be addressed by a separate group, has been absorbed into the other working groups.

Since the last meeting, four chaired working groups were active to address each of these primary focus areas (see *Annex 5* for group membership). Discussions held by the groups between the meetings were expanded upon by the entire TAC at this meeting.

6.0 Spectrum Management

Chair of the spectrum management working group Dewayne Hendricks and his group have been to trying to uncover some of the new ideas that could impact spectrum management policy and allocation. They have decided to bring in outside speakers who have provocative ideas to stimulate dialogue. One presentation was about the future of the software defined radio(SDR). It reinforced the notion that the TAC has discussed before, that the SDR is a technology key to next generation spectrum management. David Reed, the second speaker, challenged the idea that spectral capacity is intrinsically a limited resource. He presented plausibility arguments to show that with emerging technologies, especially multihop ad-hoc networking, capacity can be made to grow with the number of users. This extraordinarily valuable albeit counterintuitive benefit will only occur, however, if innovative management and operational philosophies are adopted.

6.1 Software Radio to Enable Dynamic Spectrum Management

The first invited speaker was Vanu G. Bose, CEO of Vanu, Inc. (vanu@vanu.com) Vanu is the principal inventor of the software radio technology that serves as the basis of Vanu, Inc.'s products. Vanu completed his doctoral thesis on software radio in April 1999, and received his Ph.D. in Electrical Engineering and Computer Science (EECS) in June, 1999. He received his Master's degree in EECS from MIT in 1992 and two bachelor's degrees, one in EECS and one in math, from MIT in 1988.

According to Bose, an ideal SDR would move all the functionality that makes, for instance, a PCS phone different from an LAN different from a baby monitor into reprogrammable software. There would be a generic r-f transmission and reception platform with the characteristics common to all configurations, but loaded software to turn the SDR into whatever wireless device was desired. The benefits of this approach parallel those of the personal computer. A single cost-reduced platform could be used for multiple purposes. This represents a compelling advantage for the military where personnel usually need to operate in multiple modes and bands. The SDR can efficiently replace numerous single-purpose radio sets. Another advantage is faster technology tracking where new software upgrades and signal processing programs can revitalize existing equipment. These essentially economic and convenience advantages, however, may pale in comparison to the impact that the SDR could have on spectrum usage. Because the frequency of operation, modulation, and bandwidth of deployed radios can, in principle, be changed on the fly, we can implement dynamic spectrum management schemes where users can be moved in some optimal way to make best use of the available spectrum at any given time and place. Although a fully developed scenario for implementing this sort of dynamic spectrum management is not yet available, tremendous progress has been made over the last ten years in evolving the SDR platform.

The first step in the evolution of the software radio is the modal SDR where software just controls and configures the radio hardware. Today's dual and tri-mode cell phones fit this category. The next step would be an SDR where all signal processing was reconfigurable with a significant use of field programmable logic or assembly code. Finally, to take full advantage of Moore's Law, we can envision SDRs with portable programs so that third-party providers can design radio systems and spectral management algorithms that run on commodity platforms.

At the current state of the art in SDRs, the technology is mature for infrastructure base stations, certain public safety applications, and wireless LAN/MAN / last mile uses. The base station application is appealing because it allows operators to reconfigure bases as generations of wireless evolve. SDR handsets for cellular are probably 3 to 5 years away, with total cost and power dissipation still constraining issues.

Available soon will be public safety SDRs that can be reprogrammed so communication will be seamless even though multiple, incompatible systems may exist in neighboring communities. The classic problem in an emergency occurs when the state police and FBI arrive with digital radios and meet the local police department with their FM radios scattered all over the band. They can't talk to each other and the lack of coordination hinders rescue efforts. Estimates are that more than $4 billion would be needed to give everyone across the country new hand sets today, an unaffordable solution. Vanu has built a system with two receivers and a transmitter. It can listen to two different networks, such as Project-25 and an FM network. By simply dragging and dropping icons on the screen, patches between different radio networks can be created. One could speak into the Project-25 radio and hear it on the analog radio creating patches as needed at the scene of an emergency. This could be the first market where this technology is deployed and the first market where regulatory help might be needed to get efficient deployment.

At the current time, the processor based SDR is more expensive than the components that go into a standard cell phone. For a single-standard system, application specific circuits are still cheapest. For multimode capability, the current cost crossover occurs when the radio needs to emulate more than two modes of operation. If there is a compelling need to do three things or more, then the software radio can be cheaper.

A essential feature to realize the benefits of spectrum efficiency and technology tracking will be the capability for waveform downloads to the SDR. This brings to the Commission the serious issue of platform certification to insure that there is no harmful interference - even with malicious software. There needs to be confidence that equipment will radiate within power limitations, within the allowed bandwidth, and that it can not do certain harmful things. Theoretically, it is not possible to *guarantee* correct functionality, be we need to reach a level of operational reliability that will make the SDR a reality.

Regulation seems to be off to a good start with SDR rule making. The next steps should stimulate the ideas of more dynamic spectrum allocation, and the means for downloadable waveform upgrades. If SDRs proliferate in the future as we expect, and we evolve to an environment where most radios can be reconfigured with downloads, we will need to revisit the whole concept of dedicated spectrum for specific purposes. If it becomes technically feasible to define operating parameters on the fly, we can consider replacing dedicated spectrum allocations with some type of dynamic, ad- hoc configuration plan.

The visuals for Bose's presentation can be found at:
http://www.fcc.gov/oet/tac/april26-02-docs/vanuinc-tac.ppt

6.2 How Wireless Networks Scale: The Illusion Of Spectrum Scarcity

Dr. David P. Reed (http://www.reed.com/dpr.html), dpreed@reed.com, enjoys architecting the information space in which people, groups and organizations interact. He is well known as a pioneer in the design and construction of the Internet protocols, distributed data storage, and PC software systems and applications. He is co-inventor of the "end-to-end" argument, often called the fundamental architectural principle of the Internet. Recently, he discovered Reed's Law, a scaling law for group-forming network architectures with significant implications for large-scale network business models. His current areas of personal research are focused on densely scalable, mobile, and robust RF network architectures and highly decentralized systems architectures. He was a Professor of Computer Science and Engineering at the MIT Laboratory for Computer

Science, where he helped to shape the early design of LANs and communication protocols. Dr. Reed holds a BS in electrical engineering and MS and Ph.D. degrees in Computer Science and Engineering from MIT.

The primary question that Reed is addressing has to do with the way to wireless networks scale or can be made to behave as they become more pervasive. Such scalability really matters because pervasive *computing* must be wireless, and mobility leads to a demand for connectivity and a density of stations that will change constantly at all time scales. As small geographical areas become filled with communicating devices, will we inevitably reach a point of total congestion? The conventional wisdom tells us that the capacity of the spectrum is a defined, limited resource that must be careful parsed out to maximize the public good. Indeed, much of current regulatory theory assumes that we are dealing with a limited resource. One resulting theory for achieving fair distribution is to use a property based model. So the provocative question is: *Does spectrum actually have a definable capacity?*

Under some broad assumptions, we know that the capacity of a single point-to-point link is:

$$C = W \log(1 + \frac{P}{N_0 W})$$

where C = capacity (bits/sec.), W = bandwidth (Hz.), P = power (watts), and N_0 = noise power density (watts/Hz). This gives the well known rule that channel capacity is roughly proportional to bandwidth. But "standard" channel capacity is for one sender, one receiver and a one-dimensional link, *a wire*, and says nothing about multiple senders in free space. "The capacity of multi-terminal systems is a subject studied in multi-user information theory, an area of information theory known for its difficulty, open problems, and sometimes counter-intuitive results." [Gastpar & Vetterli, 2002]

When we try to ascertain the capacity of a system of multiple radio transceivers operating in a three dimensional environment, we have often assumed that each pair of senders and receivers acts like the point-to-point link above. The capacity is proportional to bandwidth and each system interferes with the others in a way which has some analogy to noise in the equation above. The more pairs communicating, the more interference - hence the need to control the number of participants because of the impact of new interferers, or "noisemakers", on the current user's capacity. But if we take a critical look at interference, we see that its damaging impact on receivers is not a physical inevitability but rather the result of the specific design of the receiver. Radio "interference" is almost completely the result of the (linear) superposition of radio waves arriving from different directions and being added together at the antenna. No information is actually lost in the radio environment, it is just that the receiver becomes needlessly confused by a sum of signals all arriving on the same wire. Needlessly confused because the canonical receiver with one antenna port and one detector is not making use of all the information that could be made available to it by the radio space. Most of the so-called interferers are actually other signals arriving from different directions and could be separated using a smart multi-antenna receiver with multi-user detection.

This simplified example makes the point that we can not calculate the full theoretical capacity of the available spectrum in a given area by using the point-to-point equations and some measure of equivalent noise caused by interference. To do so would ignore too many of the options available to the designers of transmitters and receivers. This brings us back to the fundamental question of the information capacity of a network of N stations (transmit & receive) scattered randomly in a fixed space where each station chooses randomly to send a message to some other station. Each station, to use some jargon from current technology, is equipped to do adaptive space-time processing with multiple smart antennas and can participate in multi-hop ad-hoc networking, plus maybe a few other things yet to be fully developed. Can we find a bound for the total capacity in bit-meters/second (a unit of measure with the right scaling properties)? We can guess that the capacity increases with the generally available bandwidth, but the traditional, intuitive "spectrum capacity" model predicts that the capacity per station decreases as stations are added because of interference effects. This basic notion leads to the idea that total capacity is limited resource that needs to be somehow shared among conflicting users. It is the basis of many aspects of spectrum regulation. But is it possible that this critical notion is not inevitably true?

Reed observes that new technologies including software defined "agile" radio, spread spectrum, ultra-wideband, multi-user joint detection, and smart antennas are "constant factor" improvements. They make more capacity, but the scaling is still bounded. But if nodes repeat each other's traffic, then the transmitted power can be lower, and many stations can be carrying traffic concurrently. In this case, what is the ultimate capacity? The total capacity, $C_{Total}(N, W)$, depends on technology and architecture. Tim Shepard and Gupta & Kumar each demonstrate that C_{Total}, measured in bit-meters/sec., grows with N if stations cooperate by routing each others' traffic. But this seems to be just a *lower bound* – because other potential approaches may do better. And, since system radiated power also declines as N increases, there is additionally a strong energy cost and safety incentive to cooperate.

We know that with better architectures such as cellular, with a wired backbone network where we can keep subdividing cells, the total capacity grows linearly with the number of users. Similarly, with adaptive space-time coding, joint multi-user detection, and MIMO (multi input/output), we expect a similar growth of C_{Total} with N. Reed has discovered a number of results from multi-user information theory, network architectures, and physics which were previously considered counterintuitive. Radio wave multipath, reflections, and repeating of other users traffic can all be made to *increase* capacity, not necessarily limit it as with many current systems. Even scattering and fading introduced by the mobility of the users results in a kind of diversity that can be made to increase capacity. Repeating reduces energy radiation (adds safety), distributed computation increases battery life, and channel sharing decreases latency and jitter.

Reed reports that research is beginning to show that repeating and multi-hop architectures may have the potential to make C_{Total} proportional to N or better. This means that network capacity could scale with demand. The economic values that networks create depend not only on capacity but also on "optionality", that is, flexibility in allocating capacity to demand (dynamic allocation), in "random addressability" (e.g. Metcalfe's Law), in group forming (e.g. Reed's Law), and security and robustness. Property rights are a solution to the "tragedy of the commons" by allocating property to its most valuable uses, but property rights assume property is conserved, yet *it appears technically possible to make spectrum capacity increase with the number of users, and if made proportional to N, each new user will become self supporting!*

Reed's observations are provocative and go to the heart of many of the assumptions we have used to create a regulatory environment. More research is needed to create efficient wireless architectures that are based on networks that cooperate dynamically in spectrum use. There is need to have new incentive structures (regulatory or economic) put in place to encourage use of efficient architectures. Architectures for cooperation and constant innovation – an “hourglass” like the Internet – enabling a variety of underlying technologies, services, applications and third-party innovators need to be fostered.

An important observation by Reed is that current property models with auctions and fine-grain band management are likely incompatible with the kind of dynamic cooperation needed for dense scalability. Each time a band is partitioned in space or time, capacity is wasted Partitioning inevitable results in useless guard bands and is a kind of transaction cost. Burst allocation is capped, random addressability and group-forming value severely harmed, and robustness reduced. The more we subdivide what we believe to be a limited resource, the worse the wastage and the lack of future-proofness becomes. We need to be sure that we have a scalable model before we irreversible allocate spectrum as property.

If what Reed says is correct, frequency bands are probably not the property we want to allocate. Maybe a way to incentivise more efficient spectral usage is to license architectural designs with the objective of propagating only those with the right scaling properties. A test might be that a proposed new architecture must demonstrate that it makes better use of the spectrum than the current state of the art. Another interesting proposal would be to include a sunset provision with these architectural “licenses.” This would free future generations from being saddled with obsolete systems, and, because of the field reprogrammable SDR, is now a feasible concept.

The beauty of what Reed described is that there is a lot new thinking on the horizon. A lot of the walls that people talk about may not exist. But there is an economic impediment to the deployment of these techniques. None of these are a solution to today's problems. For example, 802.11 will probably be going along just fine for five years to meet the needs and huge demand that it is obviously generating - even without marketing. Nevertheless, it's time to start thinking of what we believe could be a better paradigm and start moving our systems toward that. The drive will come from research and out-of-the-box regulatory rethinking, and not so much the short term economic needs. Maybe we can enlist the amateurs into doing experiments with some of these ideas.

The visuals for Reed's presentation can be found at:
http://www.fcc.gov/oet/tac/april26-02-docs/Spectrum_capacity_myth_FCC_TAC.ppt

6.3 Spectrum Management – Going Forward

The noise study work as described in previous reports continues apace and we expect deliverables to be reported at the next meetings. *Annex 6* lists the project team. Assuming that many of the technological problems can be worked out, the group should try to work through some of the scenarios that could make the whole idea of spectral sharing and reuse work. Ajob for the spectrum committee to would be to outline some spectrum management alternatives for the future based on the new technologies.

7.0 Optical Networking

Stagg Newman provided an overview of major and emerging broadband access technologies. This overview was based on a documented five-hour tutorial recently presented to the Commission. It reviews broadband access technologies that could potentially be used to extend the reach of broadband in the US. Fourteen technologies are profiled. These technologies include not only specific broadband access platforms such as HFC (Hybrid Fiber-Coax) or xDSL(*any* Digital Subscriber Line)) but also access applications and architectures. Each technology's description includes basic facts about its performance, applications and architecture. Key advantages and challenges are highlighted. Guidance is provided for determining potential addressable market sizes. The entire 102-page presentation can be found at http://www.fcc.gov/oet/tac/april26-02-docs/BB-Access-Tech.pdf.

The objective of the tutorial was to help the with the Commission's understanding of the underlying facts so the right tradeoffs could be made. The FCC asked what was happening on broadband deployment around the world and what might be lessons learned from other places. As an example, why does it seem as though Korea is ahead of the US? Is it higher density – or lower cost? Or, are there policy reasons and lessons to be learned that we should be bringing back? Although the US is ahead on demand, we have probably the most expensive broadband network to roll out in the world because we have the lowest linear density and the least amount available of wireless spectrum (if one wanted to use a wireless alternative). Fiber now gets to about 5% of the business buildings in America. Considering the economics of business buildings in America and the amount spent on telecom, we probably won't rationally get beyond about 10% fiber reach in the foreseeable future. Fundamentally, it's a civil engineering problem involving right-of-way, the cost of laterals, the cost of drilling, and the like.

The profiling of the 14 different technologies of the report is mainly an analysis of reach-out to the mass markets – small to medium enterprises, and residences. For each technology there is a description, basic set of facts about performance, and an application of an appropriate architecture. There is information about addressable markets and market size. This is an issue that is important for the Commission to understand as was illustrated by the LMDS experience. LMDS was going to be the service alternative and competitor to the telephone network. The commission allocated considerable spectrum, but now the technology is not being used by anybody in the US market. We don't have the competition, and, with hindsight, maybe there were some incorrect decisions made. Part of the problem had to do with an incomplete understanding of the true addressability and the true economics.

The report addresses copper-based xDSL broadband technology for the local loop capable of providing high quality video and other bandwidth-intensive applications. xDSL targets the residential and small-to-medium enterprise market by leveraging the ubiquitous telephone network infrastructure to offer high-speed data. VDSL (Very high speed DSL) only works for loop lengths shorter than 4.5 kilofeet, limiting the size of addressable market to 20% of US households absent a major investment in bringing fiber closer to the home. Provisioning VDSL lines adds several more layers of complexity to the provisioning process. There is a need for new network equipment and additional backhaul capacity to provide VDSL service to customers not within 4.5 kft. of a central office, and this is considerably more expensive than the lower speed ADSL. With the additional capital expenditures required to extend addressability, the per subscriber cost is considerably higher and the size of the addressable market becomes an issue.

Looking at the whole family of wireless technologies and the barriers to deployment and addressable market, the key problem in the wireless technologies today is the cost of equipment at the customer premises. This includes the truck roll, the installation, and getting the signal from outside to inside of the buildings. Satellite may have an important role to those parts of the country unreachable by cable or DSL, but is still a niche technology.

Summarizing what's in the presentation package, it gives the Commission good, factual data. There are no disruptive technologies identified that can give attackers fundamental advantages over incumbents who can exploit the existing infrastructure via deploying either cable modem or DSL. Where neither DSL nor cable modems are available, satellite or fixed wireless may be an attractive option. There are technologies, like wireless, that are going to make sense in a lot of niches and in certain areas rural America. The commission ought to be in a position to encourage such use. There are technologies that will make sense in parts of the business market, but there's no one-size-fits-all solution. Service providers may need to deploy multiple access platforms. With some of these technologies that can provide a cost effective means of addressing market niches, the cost effectiveness is very dependent on the business plan of the provider, the addressability limitations of the technology, and the particular geographic data and demographics of each market.

Finally, after doing a careful analysis of broadband, the report comes to the conclusion that the critical path is not basic technology, but what really dominates the addressability is construction costs, the true nature of telephone network, operations support, the realities of propagation and meeting line of sight (for wireless), and building by building willingness to spend on telecom. Great technology, but is there enough affordability out there to justify it? It's much more about civil engineering than technology.

Another issue to consider is the assumption that the10 megabits per second that many of these alternatives are targeted at providing will be adequate. Although 10 megabits per second is fine for a single channel of very high quality video, it will probably never meet all consumer expectations for television service because of the difficulty of rapid channel surfing. Also, even when the capacity is used for two simultaneous channels, the demands of many households may not be met.

7.1 Optical Networking – Going Forward

The Optical Networking Group will produce several presentations and reports for the next meetings. For the question of the interconnection of optical transport networks, a speaker is expected at the next meeting to describe industry activities to address this problem. It appears as though most optical networks provided by different suppliers are interconnected at the electrical level where adequate standards such as SONET exist. For those limited cases where interconnection directly at optics is desired, the problem is typically addressed in an ad-hoc way by local agreement. There does not appear to be a pressing issue here for the Commission to address. To obtain closure on this item, we will need to discuss technology, standards, and market deployment of interface and interconnection points, including alternatives, complexity, cost, industry standards and the policy implications of barriers.

Optical access network technology, standards, market, and deployment will be the focus of another subgroup. The group will report on technically feasible points of connection, including the feasible points of connection for the future full-optical (Fiber to the Home – FTTH, Fiber to the Building for Business - FTTB) loop access deployment. The readout should address how it can be done, the pros and cons, and the technological and operational challenges.

Additionally, readouts on several broadband related tasks are expected

- A competitive road map for broadband access technologies including fiber access, fixed wireless, satellite, etc.
- A survey on broadband deployment worldwide, and the lessons learned.
- Fiber-haves and fiber-have-nots – *draft based on presentation at Department of Commerce workshop will be circulated to TAC for comments, additions, deletions, etc. Final to be presented at 6/12 meeting.*
- Lessons learned from the Canadian Canarie network – *Bill St. Arnaud, Senior Director of Canarie has agreed to speak 6/12.*

8.0 Consumer and Home Networking

Paul Liao, Chair of the consumer and home networking group, introduced John R. Barr who described how wireless technology might replace a scramble of interconnecting cables in the home. In a second presentation, Eric Haseltine reviewed some issues associated with content protection. He described a controversial proposal which would require each final display device to contain technology capable of first determining the rights management status of the content the user intended to play, and then intervening in the presentation in some way as specified the rights holder.

8.1 The Wireless Personal Area Network (WPAN)

John R. Barr, Ph.D., of Motorola, is Chair of the IEEE 802.15.3 Task Group involved with standardizing a WPAN. The high rate WPAN enables multimedia connectivity between portable (but not necessarily mobile) devices within a “personal” operating space. The IEEE is trying to make sure that new radios co-exist with other ones in the same shared band so they can operate together without significantly altering the performance of any other radio that's in the area. The WPAN task group started about two years ago in response to the consumer electronics industry need for a very high rate wireless personal area network good enough to down load images or transfer video between a portable device and a kiosk or a TV. The group is fine tuning the draft specification and the working group ballot expected in the June-July time frame.

What is being specified is a wireless ad-hoc data system which allows a number of independent devices to communicate. The range is of the order of 10 meters and allows some movement within this zone. A related concept is the piconet architecture which inserts a piconet controller (PNC) into the WPAN to provide basic timing and QoS (quality of service) management. Figure 1 illustrates how a WPAN with its PNC might be configured. Note how in this model we actually have a device that controls who gets access to the channels. This is a little different than the wireless LAN because the wireless LAN is defined very much like the Ethernet with a shared multiple access-type channel.

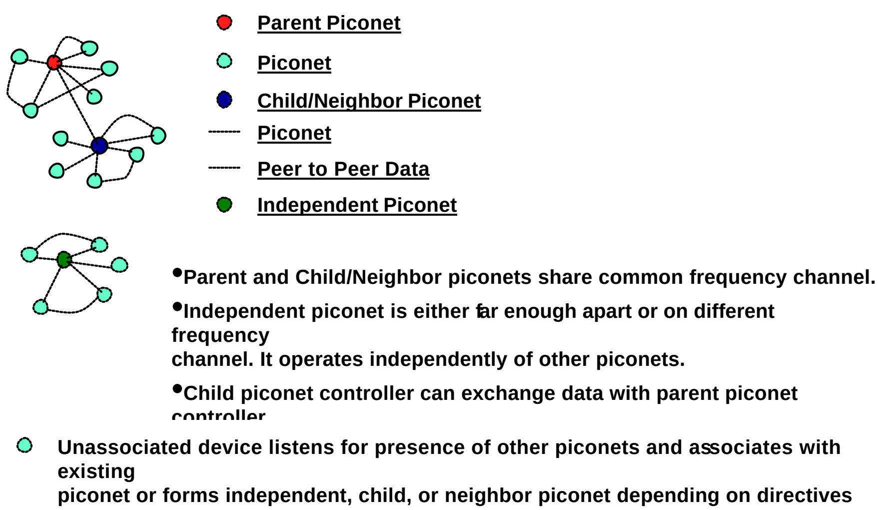

Figure 1: ***WPAN Topology*** ***Source:*** Motorola

The main characteristics of the IEEE 802.15.3 high rate WPAN are a range of at least 10m, with up to 70m possible. The data rates, currently up to 55 Mb/s, are to be increased to 100-400 Mb/s. Mobile devices can join and leave the piconet dynamic topology often with less than 1 sec. connect times. It is an ad-hoc network with peer to peer connectivity and multimedia QoS provisions with time synchronization for application requiring it. It is designed to support low power, low price point, low complexity, small form factor portable devices. Adequate security and authentication is included to prevent eavesdropping. It is, however, designed for a relatively benign multipath environment with RMS delay spread <25ns in a personal or home space.

The main applications 802.15.3 are expected to be video and audio distribution such as high speed transfer from a digital camcorder to a TV screen, between video gateways and multiple high definition displays, interactive video gaming, and high speed transfer between printers, scanners, digital still cameras and kiosks.

The 2.4GHz physical layer has five selectable data rates from 11 to 55 Mb/s. There is a specified 15 MHz channel bandwidth with 3 or 4 non-overlapping channels. The 3 channel mode aligns with 802.11b for coexistence. Compared to 802.11, an 802.15.3 2.4GHz system causes less interference since it occupies a smaller bandwidth and transmits at lower power levels. It detects and monitors for active channels dynamically, and adjusts channels and power.

Currently, an alternate study group (802.15.3a) is investigating the creation of an alternate physical layer to address even higher data rate applications with a goal of more than 110Mbps at 10 m, and more than 400 Mbps at 5 m. Ultrawideband is a potential candidate this application.

The visuals for Barr's presentation can be found at:
http://www.fcc.gov/oet/tac/april26-02-docs/FCC-TAC-802.15.3-overviewNOPICT.ppt

8.2 Digital Content Protection

Digital Content Protection is a very complicated problem. TAC member Eric Haseltine of Walt Disney Imagineering outlined some of the issues and showed why no single solution seems possible. Content users are not just consumers but are there are also universities who, for example, want to do distance learning, and there are people, like at libraries, who have other kinds of fair use requirements. Then there are the special needs of the disabled. The European Commission even has a concern that whatever content protection measures are put in place shouldn't in any way interfere with the enjoyment of people who may not have the full use of controls. Figure 2 illustrates the components, each with their own set of stakeholders, that must be taken into account in dealing with this issue.

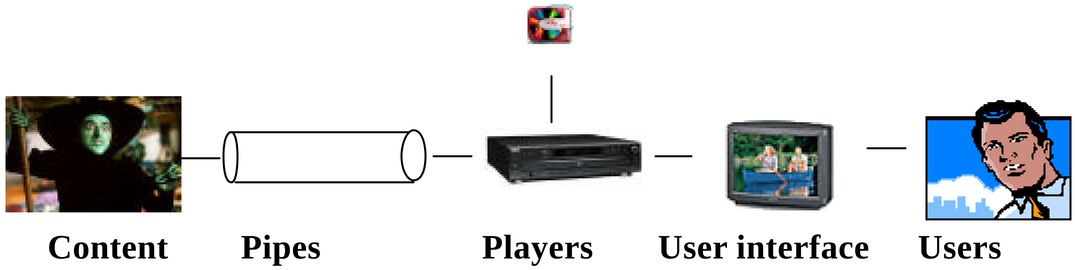

Figure 2: ***Digital Media Landscape*** ***Source:*** Walt Disney Imagineering

Probably the one of most important concerns to the content industry right now is the issue of peer to peer redistribution of content. Someone can go into a theater with a digital camcorder and create a pretty decent looking digital copy ready to put up on the Internet. We all know that there's some good content up there right now. Similar things can be done with DVDs, and then shared peer to peer from one personal computer to another. With the advent of broadband and massive storage in the home, this is becoming a real concern now for movie makers. A fundamental problem with peer to peer is that one really can't detect or trap "offending" packets on the Internet very easily. No one realistically believes that downloads like this can be prevented. One approach is to try to act *after* the material is acquired (or stolen), downloaded, and is on someone's personal machine. The problem is that within the device the PC has multiple data inputs, multiple data paths, multiple storage devices and multiple outputs. Given that there are all of those different ways of getting signals around, some say it's just impossible that one could ever solve this problem. Most people in the industry agree that from a theoretical point of view, it actually is impossible. There's no measure you can put in that is going to totally stop the problem that the content owners feel they have because someone who is really dedicated is always going to be able to do as they please. Nevertheless, there are proposals that purport to manage the problem to the point where economic returns can still be made on content investment.

There are several ideas being proposed to tackle the problem of controlling unauthorized presentation of content. One of them is, of course, DRM (Digital Rights Management). The DRM idea is to wrap the content in a secure container that has a key. There is a key management system which generally requires a return path between the content provider and the consumer. Typically, there is a handshaking that goes on that validates the users position. Then, there are things that are embedded in the content itself which instruct equipment as to how it is to be treated. These are usage rules that say under what conditions it can be played, copied and so forth. The conclusion that some of people who are concerned about content are coming to is that if there is a solution in the PC world, it's probably going to have to be right down next to the final common path or display. There are just too many different ways otherwise to circumvent security. In a media player, for example, all one would have to do is produce an open source player complete with its own kernel ready to drop it into a PC and all protection would be trivially bypassed.

The conclusion that many rights stakeholders have reached is that they want reproduce the controlled environment that exists in a consumer electronics device. The model leads to the idea of putting something right down in the part of the computer that puts the bytes out for display. A problem, of course, is that one can still take a camera, look at the output of a legitimate copy and then distributes it via the peer to peer system. Watermarking is a proposed solution. A watermark is hidden information that a camera recording the image would also copy. When the content is shared on a peer to peer system, the computer sees the watermark and can then check to see if the copy is accompanied by a the proper DRM message. When one tries to play the material on a PC, the watermark detector checks for all of the right DRM information and decides whether or not to display the content, or to display it with some type of banner. Figures 3 and 4 illustrate some modes of this concept.

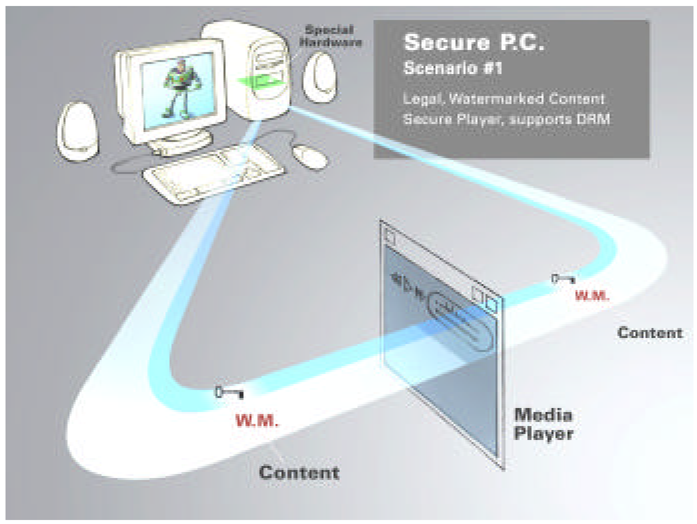

Figure 3: ***DRM Displaying Authorized Content*** ***Source:*** Walt Disney Imagineering

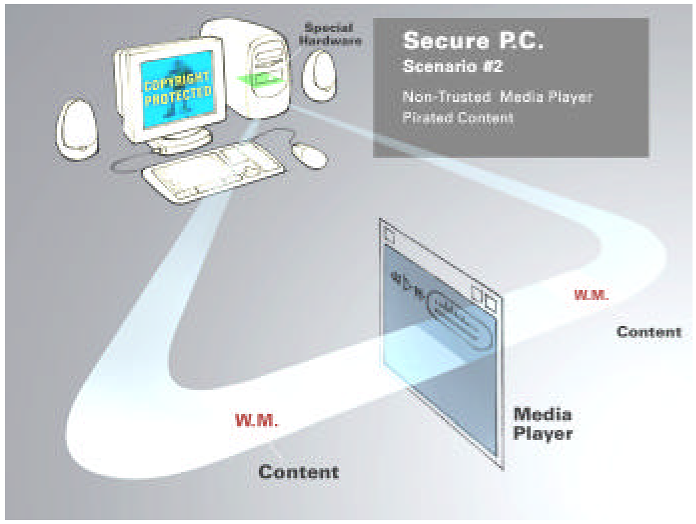

Figure 4: ***DRM Blocking Pirated Content*** ***Source:*** Walt Disney Imagineering

Needless to say, this previously described method of rights management is very controversial. There is the technical question of whether of not it can be made to work in a way that is not easily circumvented. A problem with watermarks right now is that they can be fairly easily defeated by rotations, scaling or other means, or detected and then removed. There is always the issue of cost. But beyond these technical issues, there is the overarching question of the practicality of equipping every potentially offending display in the world with a detector in special hardware which will prevent the owner from displaying material which someone else has decided it is not appropriate for them to view. This is fundamentally a policy question which is beyond the scope of the TAC. The TAC, however, can provide some technically supportable guidance. For instance, if any of the proposed solutions can be shown to be trivially circumventable, overly expensive, or especially deleterious to normal operations, proposed rules demanding their use would need to be considered carefully.

A key issue here is that there are many groups each with legitimate but different needs. The content industry has to be able to make a profit on the investments that they make. The same is true for the CE and IT industries. A costly or obnoxious requirement on the PC could be deadly to the CE and IT industries. If they can't make money then it's not practical. Consumers also have legitimate rights for fair use. They should be able to record just as they do today for time shifting and for reuse around the house. And, they should be able to do it in an uncomplicated transparent way. The real challenge is to find the solution which optimizes the needs of all the legitimate stakeholders. We must also realize that the citizen's representatives are about as varied in opinion about this as are the computer manufacturers and some of the content owners. There are probably several viable solutions that could give fair use and yet protect the media companies, but those will only be explored if the dialogue does not become polarized.

Something that frequently gets misconstrued in the thinking of people when they talk about copyright protection is the issue of the total prevention of copying. Most of the video content that is available and would be offered this way is being proposed to be offered under what's called the copy-once scenario which allows consumers to make copies for their own use. The no-copy scenario just relates to certain first-run motion pictures offered electronically on a pay-per-view basis.

In addition to the citizens and the content owners there are the “pipe” people who sell services that people can use in conjunction with recorders within their own homes. A difficulty is that if they put a network, a pipe system, into place without any controls in it at all, the “horse is out of the barn” and we can't even have a debate. If distribution equipment gets into the field that has no capability whatsoever of protecting anything we will never be able to get high value content onto these systems because it will obviously go right through to the Internet. Again, it’s the peer to peer redistribution that’s more of a problem than the recording.

It is instructive to understand why the consumer electronics companies are not strongly opposed to copyright protection. It's simply that if there is no high valued commercial content because of the reluctance to use insecure facilities, then equipment people don't have a business either. A good positive example was the DVD which has been a very successful business overall. Probably the key to the success of the DVD business is the fact that the studios are willing to release their movies on DVDs, and release them at very early schedules. They do that because they have confidence that DVD users will not easily be able to take the content and send it over to the Internet. It was possible in the new DVD product to include these restrictive features, but for equipment with a history, like the PC, mandating what many users would view as unprecedented and expensive antifeatures could be a huge negative for the industry - especially if old or off-market computers are widely available without the restrictors.

The visuals for Haseltine’s presentation can be found at:
http://www.fcc.gov/oet/tac/april26-02-docs/Digital-Content-Protection3.ppt

7.3 Consumer and Home Networking – Going Forward

An important issue that should be addressed by this group is the impact of consumer and home networking on unlicensed spectrum bands This potentially troubling situation is developing at a pace that a committee like the TAC can barely keep up with. With respect to rights management, we have to identify rational *technological* issues that we can address that will help play a constructive role in the whole debate.

8.0 Access to Telecommunications by Persons with Disabilities

Larry Goldberg described how the group has been looking at a few different issues, one of them being a carryover from the previous TAC. It is the problem of awareness of designers to barriers that can occur as media and information technologies advance and evolve. It is the question of what we can do proactively about the losing of access to content as technologies change. The group expects to go forward with creating a document that would be helpful for technologists in the future. We have a previous document about protecting features in media when moving from the analog to digital world - *Don't Regress When You Compress*. We now also need to focus on the user interface and what features could be lost there. As emerging media comes into our home, the consumer's first step is to learn how to navigate among a vast array of choices and options. For a person with a disability, becoming acquainted with a new navigational style can be a major challenge. Some solutions are already in prototype, and some on the market can help resolve that question on the network over broadcast or built into technology.

Larry showed an example to help people think about the issues. A barrier that exists today has to do with listening to the video description channel when there's no obvious interface to access it. Typically, one has to turn on the Spanish channel and that's where the video description for the blind will be. It represents the kind of problem we want to avoid as we look down the road. As an example of low-barrier design, he showed a DVD on the market now that has all of the good access features on it. There's a marker channel that comes up in the beginning and a talking menu that a blind person or someone who is struggling with the DVD has access to immediately. If you don't want the talking menu, you can ignore it and it moves to other accessible options as was demonstrated.

The demonstration pointed to a prime task of the subcommittee, that is, producing a white paper with the kinds of red flags the emerging technologists will need so that the interfaces can be as accessible as the content itself.

9.0 Robustness, Reliability, Integrity and Security of the Network

An important issue for this work area is that of content protection and rights management. This item is now being addressed by the Consumer and Home Networking group. Many of the other items originally directed to the working group proposed for this topic are being adequately covered by other groups sanctioned by the Commission. We need not duplicate the work being done by the NRIC (Network Reliability and Interoperability Council). The TAC monitors and has liaison to the FCC NRIC. Because of this evolution, the work of this group has been absorbed into the other four working groups.

10.0 Procedure for Technical Work

Time at the end of the general meeting was allocated to breakout sessions of the individual working groups. At these sessions, decisions were made to invite expert speakers to future meetings, and work assignments were clarified.

Generically, the preparation of technology roadmaps may be one of the most valuable types of deliverables for the Commission. Maps are not necessarily focused on particular problems, but paint a picture of much of what's happening in a particular area technologically. Maps could be documents outlining where we see technology going and what issues might arise. They could be a logical output for one or more of the working groups.

Annex 1: Official Meeting Minutes

A VHS videotape of the Friday April 26, 2002 meeting serves as the set of comprehensive minutes of that meeting and represents the official archive. Copies of the meeting tape can be obtained from the Commission's contracted copier, In Focus. They may be reached by phone at: +1 (703) 843 - 0100 *ext.* 2278.

This report is a reorganization and distillation of discussions at the public TAC meeting and includes some supporting information produced between meetings. It is written for the purpose of facilitating the ongoing work of the Council and as an informal summary for those who may be interested. It is *not* the minutes, nor does it, per se, necessarily represent the final recommendations of the TAC as a whole.

Annex 2: Addresses of Current TAC Members

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Annex 3: FCC staff

FCC staff available to address questions from the TAC:

General Issues:

Kent Nilsson: Special Counsel and Deputy Chief, Network Technology Division
Office of Engineering & Technology, FCC
KNILSSON@fcc.gov
Phone 202-418-0845

With respect to specific Federal Advisory Committee Act (FACA) questions, a resident expert is FCC attorney:

Paula Silberthau: Attorney, Office of General Counsel
PSILBERT@fcc.gov
Phone 202-418-1874

Additional FACA information is at the Office of Government Policy web page at:

http://www.policyworks.gov

FCC staff associated with the TAC are:

Edmond J. Thomas, Chief of the Office of the Engineering and Technology
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Jeffery M. Goldthorp, Chief, Network Technology Division, Office of Engineering and Technology (Jeff is the new TAC Designated Federal Officer)
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Julius Knapp, Deputy Chief, Office of Engineering and Technology,
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Paul Kolodzy, OET Senior Spectrum Policy Advisor; Chair, FCC Spectrum Policy Task Force
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Bruce Franca, Acting Chief, Office of Engineering and Technology,
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Peter Tenhula, Senior Legal Advisor, Office of Chairman Michael Powell,
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Annex 4: Biographies

Edmond J. Thomas

Chief - Office of Engineering and Technology, FCC

Edmond Thomas in his 36-year career has held senior positions in R&D, strategic planning, operations, regulatory matters, and telecommunication network design and implementation. On February 1, 2002, he was appointed Chief of the Office of the Engineering and Technology (OET) at the Federal Communications Commission. Prior to joining the Commission, Mr. Thomas served as President and CEO of RSL USA, a $500 million dollar international telecommunications company. In 1998 he was named one of the 50 most influential people in long distance by Phone Plus Magazine. Prior to his tenure at RSL USA, Ed was President of Science and Technology at Bell Atlantic. In this position he was responsible for Bell Atlantic's new products and service development. In this position he also had full operational and P&L responsibilities for Bell Atlantic's large customer data products and services. He has also served on the academic advisory boards of the University of Colorado, the Polytechnic University and the State University of New York College of Technology.

During his career, Mr. Thomas has been responsible for many innovative endeavors, some of which include:

- Grew RSL USA from a $120 million in revenue to $500 million in one year while improving profitability by a factor of 5.
- Analyzed and negotiated several $100 million plus acquisitions.
- Redesigned and streamlined RSL USA's business by integrating four stand alone businesses into one.
- Led the Bell Atlantic's Science and Technology Inc. (an organization of over 700 people) to ISO/TicKIT certification.
- Pioneered a new approach to organizational and work process redesign. Combined technologists, psychologists, and anthropologists as well as union and management into organizational design teams. This approach resulted in documented savings in excess of $100 million for Bell Atlantic.
- Developed and brought to market the first telephony based speech recognition system. Licensed the technology to US west and Southwestern Bell.
- Established Bell Atlantic as a premier developer and user of expert systems. As a result, Bell Atlantic was named a runner up in the global competition for the Adleman Award.
- Pioneered the use of global information systems in the prediction of signal quality for mobile telephone networks.

Mr. Thomas has lectured many times at industry forums and at the university level on the future of telecommunications and technology applications and impacts. He is also the holder of several patents in the area of data and voice communications. He is on the Editorial Advisory Board of the Journal of Network and System Management and is a senior member of the Institute of Electrical and Electronic Engineers.

ETHOMAS@fcc.gov

Jeffery M. Goldthorp

Chief - Network Technology Division, FCC

Jeff is Chief of the Federal Communications Commission's Network Technology Division, where he leads a technical staff in advising the Commission on the public policy ramifications of emerging network technologies. He is Designated Federal Officer of the Network Reliability Council and the Technology Advisory Council. He also serves on the FCC's Homeland Security Policy Council.

Before joining the FCC in November of 2001 Jeff was General Manager of the Network Access Engineering Services practice at Telcordia Technologies. Jeff had profit and loss attainment responsibility for a $10M consulting business that provided expert-based systems engineering services on emerging local access technologies including DSL, HFC, FTTN and Fixed Wireless.

From 1995 – 1996 Jeff was Operations Manager of Telcordia's $40M Emerging Networks Business Unit where he was responsible for strategic planning, project management and operations planning.

From 1996 – 1997 Jeff was Telcordia's Account Executive to Ameritech's New Media Enterprises venture where he identified and closed on $5M in new business for Telcordia.

Jeff has also served as Product Manager for Bellcore's Integrated Access Technologies product, Project Manager for Bellcore's Fiber-in-the-Loop project and lead developer of Telcordia's GR-303 testbed. Jeff also was Director, Network Technology Quality Improvement from 1989 – 1991.

Early in his career Jeff performed laboratory and computer simulations of advanced loop transmission systems to characterize performance in the presence of transmission impairments such as crosstalk, bridged-taps and gauge changes.

Jeff holds a patent for a DSP-based near-end crosstalk simulator that is in use today in Telcordia's laboratories. Jeff was also founder and co-owner of a designer glass business.

Jeff earned a BSEE from Lehigh University and a MSEE from Princeton University. He is a member of Phi Beta Kappa, Tau Beta Pi and Eta Kappa Nu.

Jeff lives with his family reside in Falls Church, Virginia. He has been active as a soccer and a little league coach.

JGOLDTHO@fcc.gov

Annex 5: Working Groups

Current list of working group membership. Note that the TAC Executive Director is always a member of all committees**.**

Ongoing TAC information is posted at **http://www.fcc.gov/oet/tac/**

Spectrum Management/ SDR/ Noise Study:

Hendricks, Dewayne, CHAIR
Bellisio, Jules
Boakye, Kwame
Farber, David
Ferren, Bran
Hatfield, Dale
Hemrick, Christine
Jackson, Chuck
Kontson, Kalle
Lapin, Gregory
Lu, Willie
Negus, Kevin
Newman, Stagg
Roberson, Dennis
Setos, Andrew
Shah, Nitin
Singer, Barry
Stevens, Jessica

Optical Network Issues:

Newman, Stagg, CHAIR
Bellisio, Jules
Boakye, Kwame
Briggs, Fred M.
Estrada, Susan E.
Farber, David
Hemrick, Christine
Kahn, Kevin C.
Lucky, Robert W.
Ransom, Niel
Sharp, Gerald
Stevens, Jessica

Consumer and Home Networks:
Liao, Paul, CHAIR
Bellisio, Jules
Green, Richard
Haseltine, Eric
Jackson, Chuck
Lapin, Gregory
Lim, Wah
Negus, Kevin
Roberson, Dennis
Setos, Andrew
Shah, Nitin
Sharp, Gerald
Singer, Barry
Stevens, Jessica
Vanderheiden, Gregg
Zitter, Robert M.

Access to Telecommunications by the Disabled:
Goldberg, Larry, CHAIR
Bellisio, Jules
Liao, Paul
Vanderheiden, Gregg

Annex 6: FCC TAC Noise and Interference study

The project team for the FCC TAC Noise and Interference study is as follows:

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